



# MULTIMOLD: Advancing In-Mold Electronics for Next-Generation Manufacturing

## Reimagining Injection Molding Technology

Film insert molding and in-mold decoration have become established techniques in injection molding electronics (IME), enabling the production of 3D-shaped human-machine interfaces with seamlessly integrated graphics and sophisticated designs. The technology offers compelling advantages: highly integrated compact systems, enhanced durability, reduced assembly requirements, cost-effective production, and lightweight product architectures.

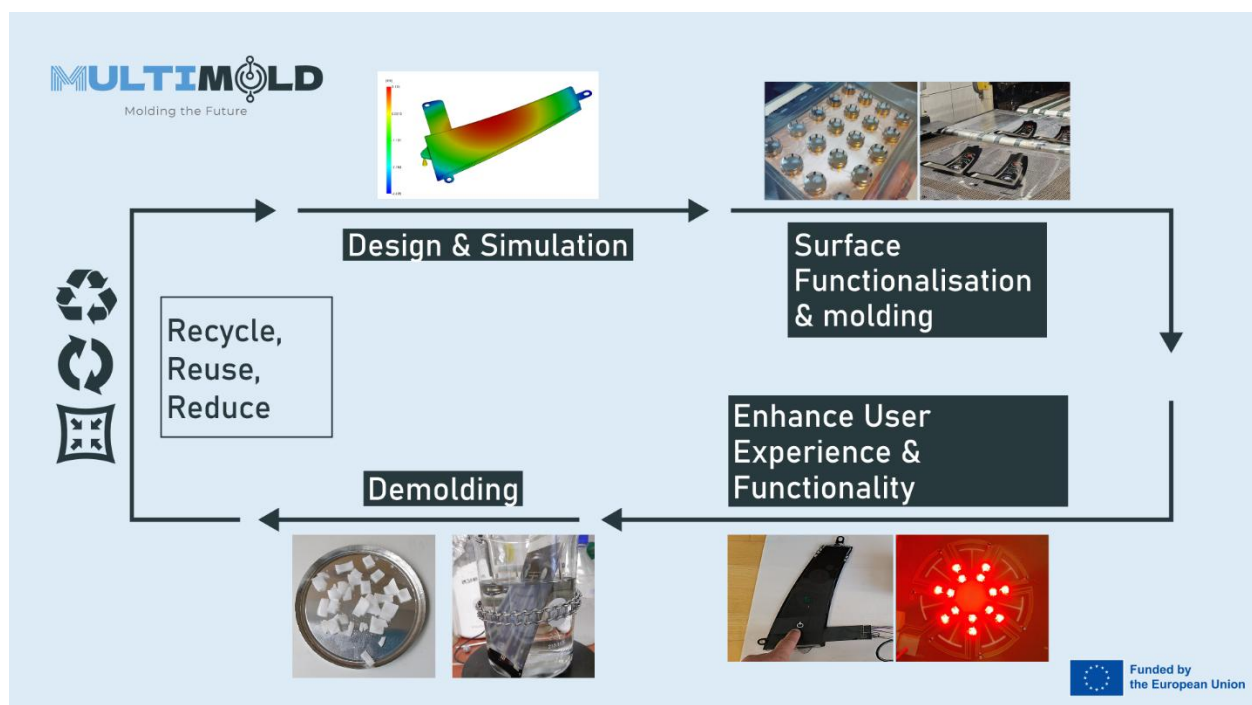
**Yet current IME solutions face critical limitations.** Capacitive sensors—the industry standard—fail with cold fingers or gloves and provide no haptic feedback. While individual manufacturing sub-processes achieve impressive yields of around 99%, the overall process yield drops significantly. Today's multi-material IME products resist recycling efforts, falling short of EU sustainability and circularity requirements. Heat from LEDs positioned near capacitive sensors compromises durability and degrades user experience.

MULTIMOLD addresses these challenges head-on, **targeting improvements in user experience, production yield, durability, and material recyclability** to deliver the next generation of injection molding electronics.

# The MULTIMOLD Approach

This Horizon Europe project tackles IME's current limitations through three key innovations: **printed piezoelectric sensing, 3D-shaped flexible PCBs, and material stacks** optimized for recyclability and reuse.

The project focuses on real-world applications demanding reliable operation in harsh environmental conditions: **industrial control panels, automotive user interfaces, and condition monitoring systems for wind turbines**. MULTIMOLD demonstrators integrate advanced electronic functionality with **multimodal sensors, haptic feedback, and power supply systems**, together with micro- and nanostructured functional surfaces offering light-guiding, antibacterial, anti-icing, easy-to-clean, and aesthetically appealing properties.

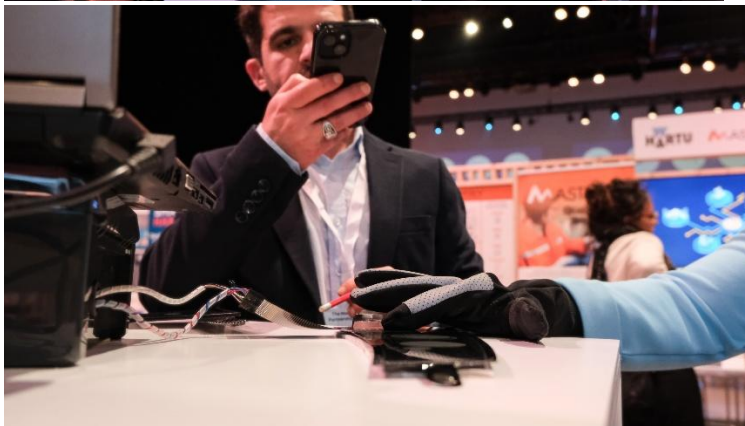


## Breakthrough Results from 1st Generation Demonstrators

### Technological Achievements

The first 18 months of MULTIMOLD have yielded impressive technological breakthroughs. **Piezoelectric touch buttons** now respond reliably to pressure input while wearing gloves, in humid environments, and even underwater—dramatically expanding IME usability in **human-machine interfaces**.

The project successfully **demonstrated 3D-formed flexible PCBs** within the injection molding process. An automotive HMI prototype incorporates piezoelectric sensors and illuminated touch buttons that function flawlessly on vehicle exteriors in highly humid conditions. **An industrial HMI** integrates haptic actuation with 3D-formed flex PCBs, achieving high integration density for LEDs and piezoelectric sensors in confined spaces. **FlexPCBs in 3D shaped environments** make In-mold electronics compatible with conventional soldering techniques and thus enable higher integration and power density than printed electronics alone, opening possibilities from LED and sensor integration in tight spaces to complete electronic circuits in demanding environments.



Perhaps most significantly, MULTIMOLD achieved the **first successful overmolding of sensitive electronics including batteries**, creating fully self-powered sensor technology encapsulated through injection molding. This breakthrough enables reliable sensor systems for harsh conditions, as demonstrated on wind turbine rotor blades.

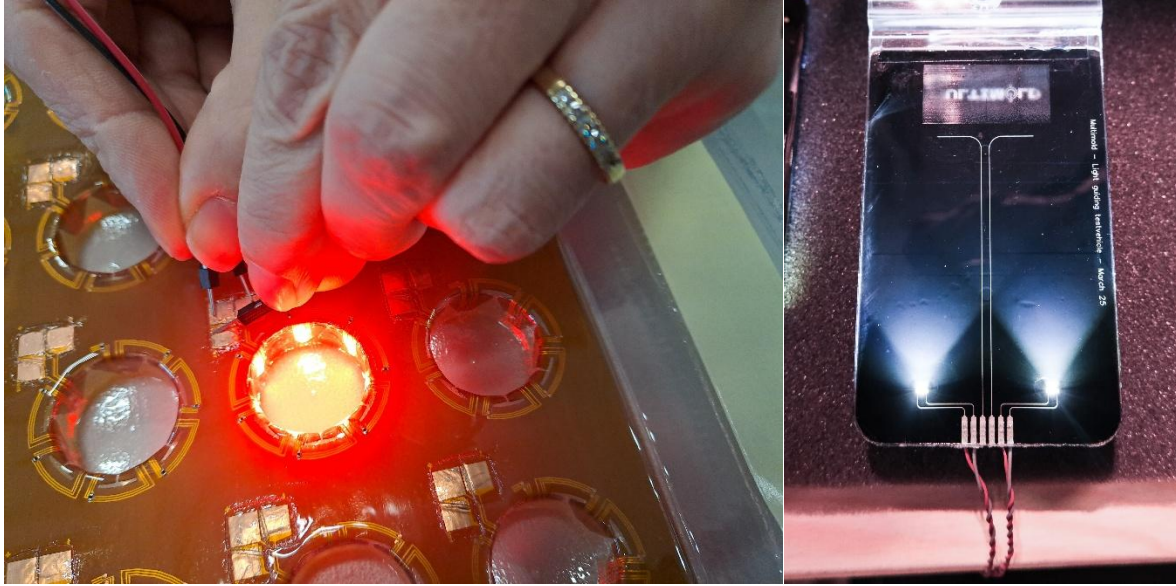


## Sustainability and Circularity Progress

The project has made **substantial progress on sustainability goals**. A dedicated testbed allows the evaluation of **different material combinations in IME recycling trials**, effectively separating plastics from electronics. This work generated comprehensive life cycle assessment (LCA) data for the production phase across different IME approaches.



To enhance process reliability and reproducibility, the team implemented **FEM and optical simulation to support injection molding and mold fabrication**. A custom data storage system provides cloud access to production data for analysis, while a digital product passport framework improves process yield and identifies critical failure mechanisms throughout the production chain. **Advanced light management** using microstructural elements has been evaluated alongside fabrication approaches for microstructured molds using direct laser writing and grayscale laser lithography.



## Scientific Contributions

The 1<sup>st</sup> GEN demonstrators delivered significant scientific advances in in-mold electronics and smart manufacturing. The successful integration of piezoelectric sensing in injection-molded components proved **reliable touch functionality in challenging conditions**—underwater, with gloves, and with various objects. The **first-ever demonstration of embedding batteries and solar cells via overmolding** validated encapsulation strategies for autonomous sensor systems in harsh environments.

Confirmation of 3D-formed flexible PCB feasibility enables high-density electronics integration in confined geometries. **Material combinations** were systematically evaluated for recyclability and circular economy potential. Laser-based micro structuring techniques for mold fabrication demonstrated improvements in light management, adhesion, and haptic user interaction within injection-molded components.

## Strategic Impact on European Manufacturing

**MULTIMOLD strengthens European manufacturing capabilities** by consolidating PCB production and plastic part assembly into a single injection molding process, **reducing dependence** on low-wage Asian manufacturing. This advanced technology creates opportunities for highly qualified employment across Europe, demanding sophisticated mechanical engineering and simulation expertise.

By establishing a **clear pathway for next-generation electronics fabrication** and addressing key technological barriers to in-mold electronics adoption, the project enhances European

**competitiveness and technological sovereignty.** MULTIMOLD positions the EU at the forefront of innovative manufacturing technologies with strategic implications for industrial policy and economic development.

## Looking Ahead

The innovations developed through MULTIMOLD are overcoming in-mold electronics' current limitations by demonstrating reliability, sustainability, and multifunctionality across applications from human-machine interfaces to sensor systems in extreme environments. The project **continues advancing toward 2<sup>nd</sup> generation demonstrators** that will further validate and refine these breakthrough technologies.

Stay updated on [MULTIMOLD developments](#) through the project's [LinkedIn](#) and [X](#) channels as the team works toward realizing the full potential of next-generation injection molding electronics.